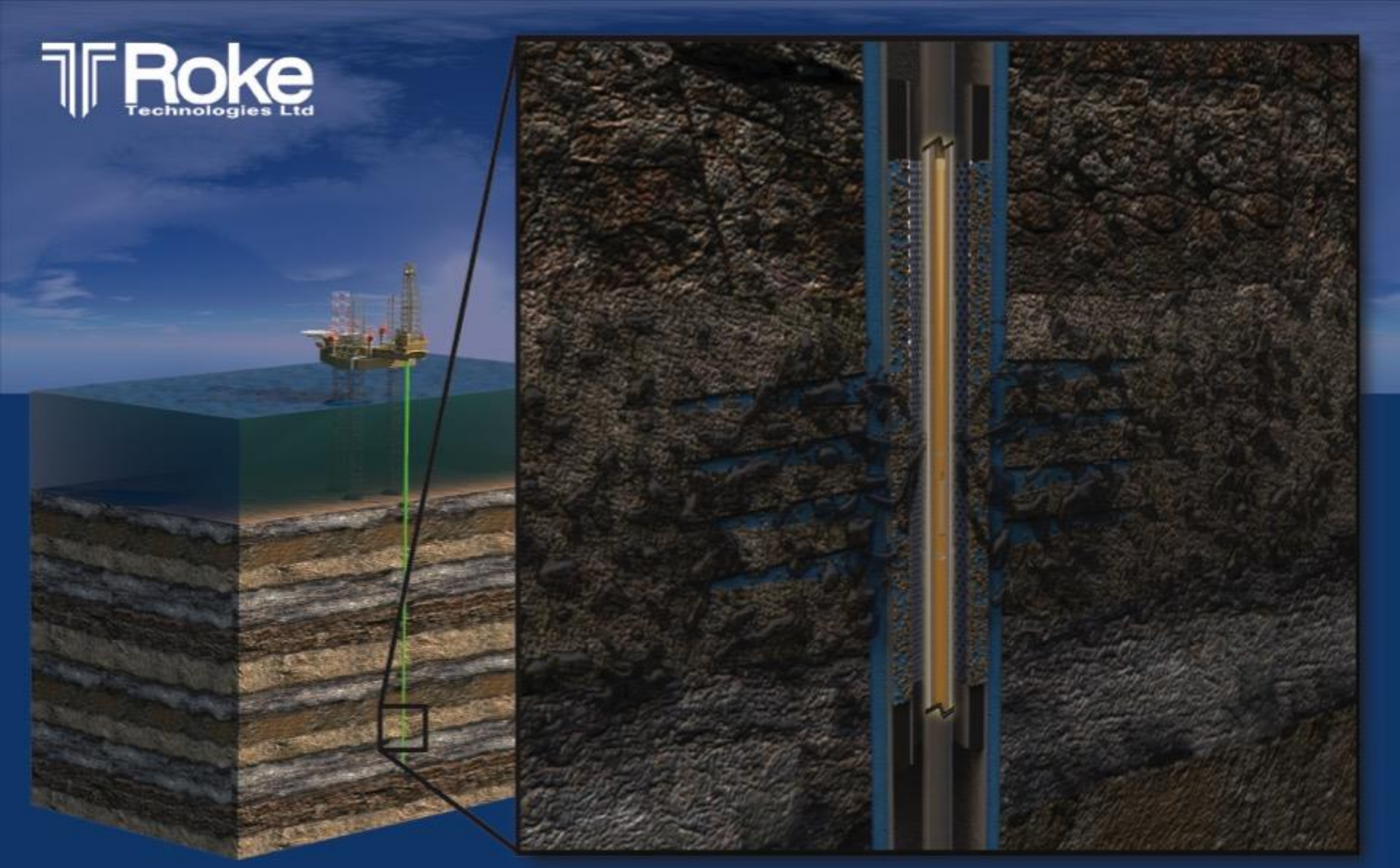


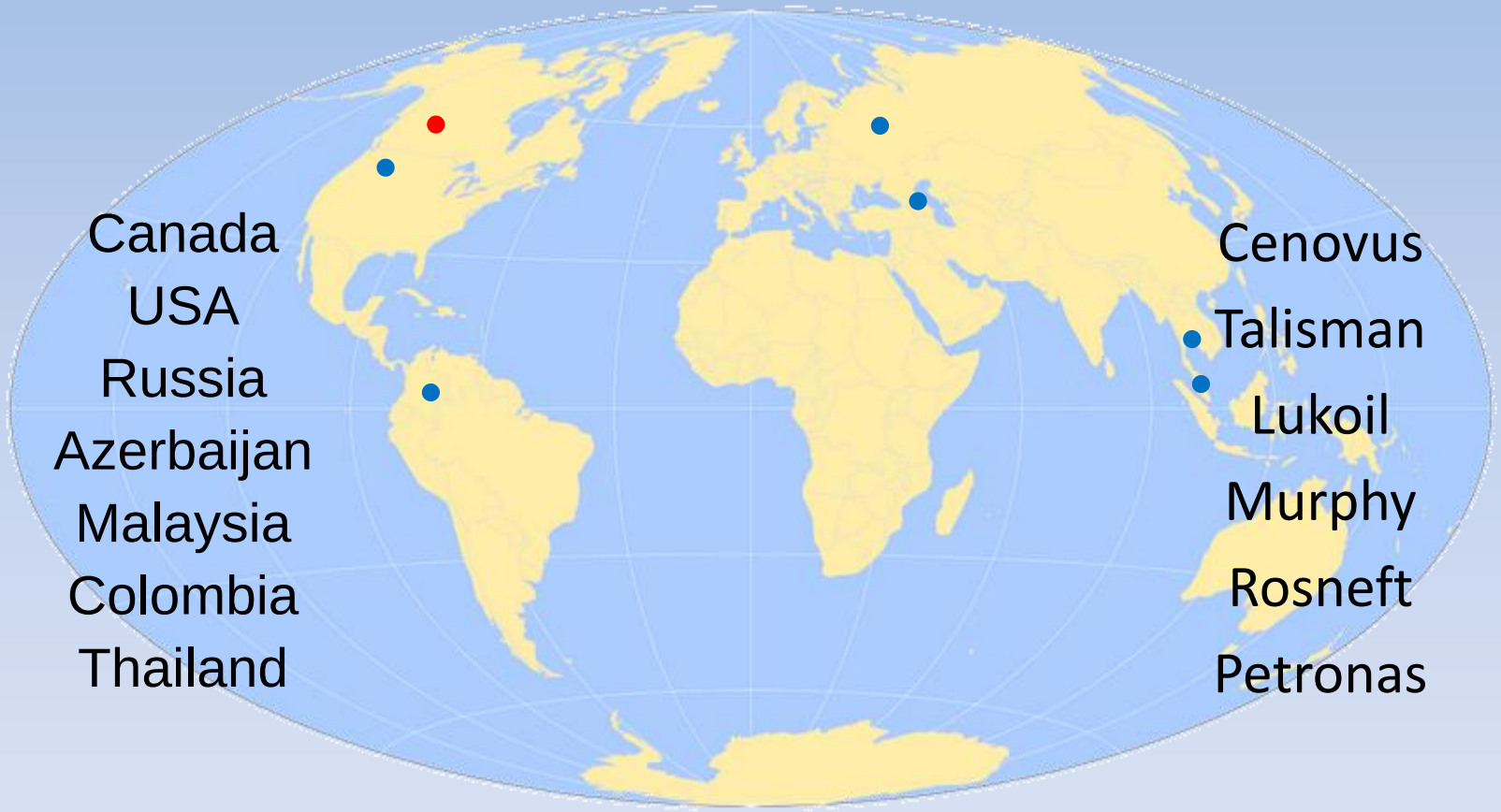
Quad Neutron Applications and Benefits

2016

Quad Neutron Technology

- Downhole nuclear measurement device designed for thru pipe reservoir and formation evaluation.
- Is an excellent open hole formation data alternative
- Replaces pulsed neutron technologies for thru pipe reservoir monitoring and evaluation

Quad Neutron Locations & Customers

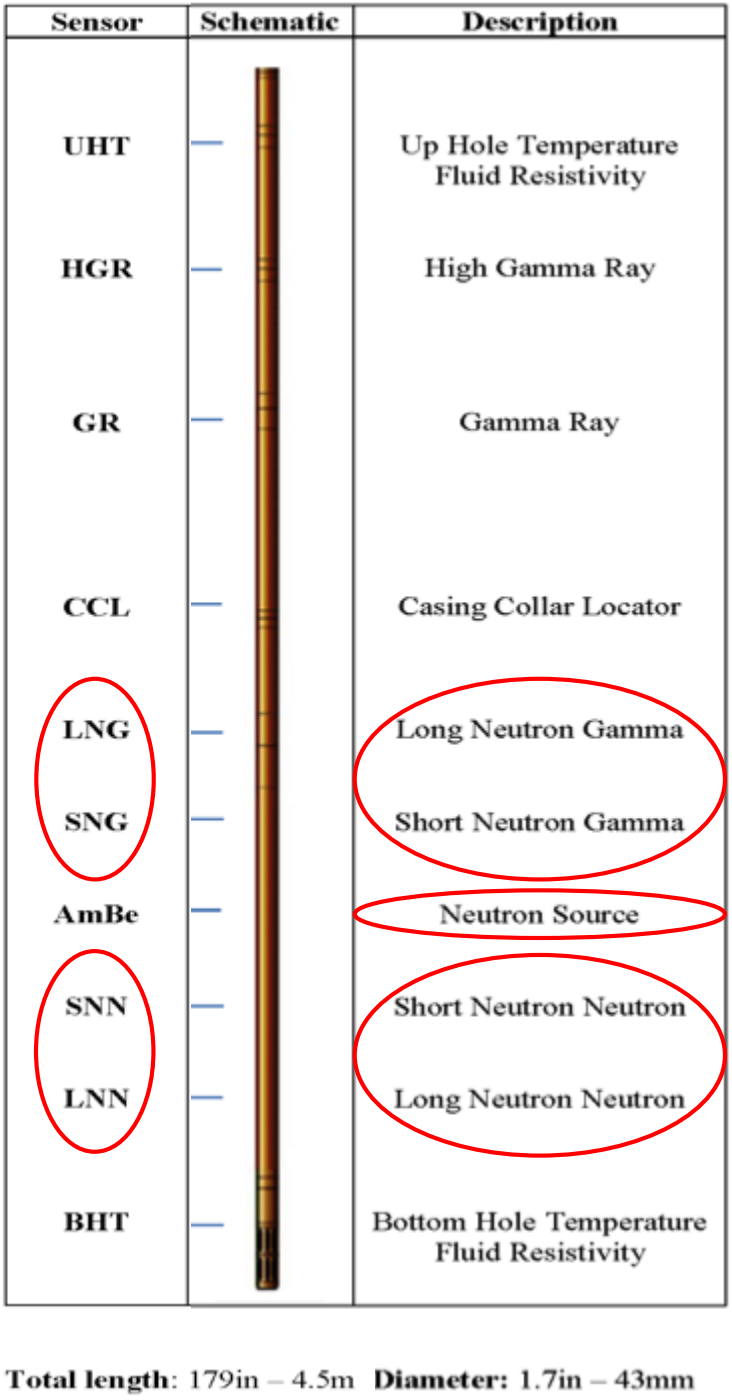


Canada
USA
Russia
Azerbaijan
Malaysia
Colombia
Thailand

Cenovus
Talisman
Lukoil
Murphy
Rosneft
Petronas

Quad Neutron

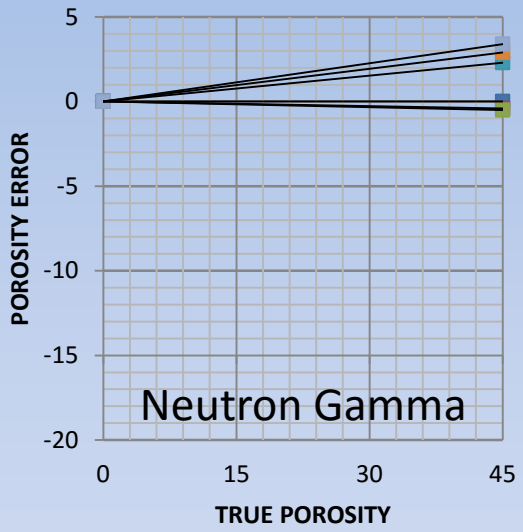
- Slim tool, 1 11/16” (43mm) OD
- Can be run in memory or real time
- Combines two physics
  - Neutron Neutron
  - Neutron Gamma
- Utilizes 6 Curie $Am_{241}Be$ Neutron Source
- DOI variable with the formation fluid – 0.8 to 1.5 m
- Provides Saturation, Porosity, Clay Volume & Relative Permeability
- Limitations: 150 C (305 F), 15K PSI, requires liquid in the inner most tubular

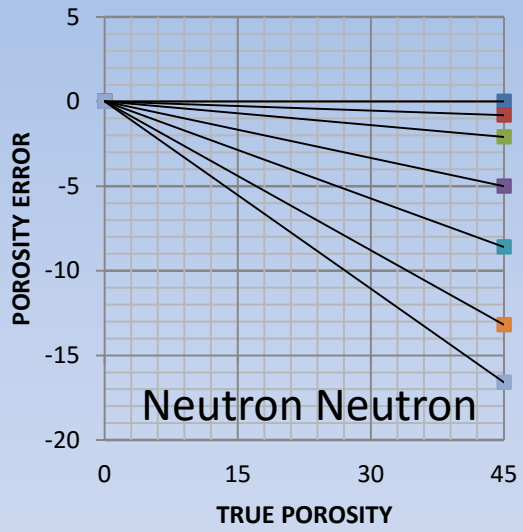


Quad Measurement Physics

- Neutron & Gamma based physics
- Source: AmBe 241 – Fast Neutron Source
- Neutron Thermal Neutron
  - Slows to “thermal” energy as it interacts with matter.
    - Hydrogen and Carbon are top thermalizers
  - Thermal neutrons will be “captured” by other atoms.
    - High capture rate will reduce the neutron counts measured by the tool
    - Chlorine, Boron and Iron have high neutron capture probabilities
    - Oxygen and Carbon have the two worst capture probabilities
- Neutron Gamma
  - Neutron Induced High Energy GR from
    - Neutron collisions with nucleus
    - Thermal Neutron capture
    - Neutron ionization as neutron passes thru electron fields
  - Gamma Ray counts are reduced by high density materials.
    - Iron i.e. pipe, packers

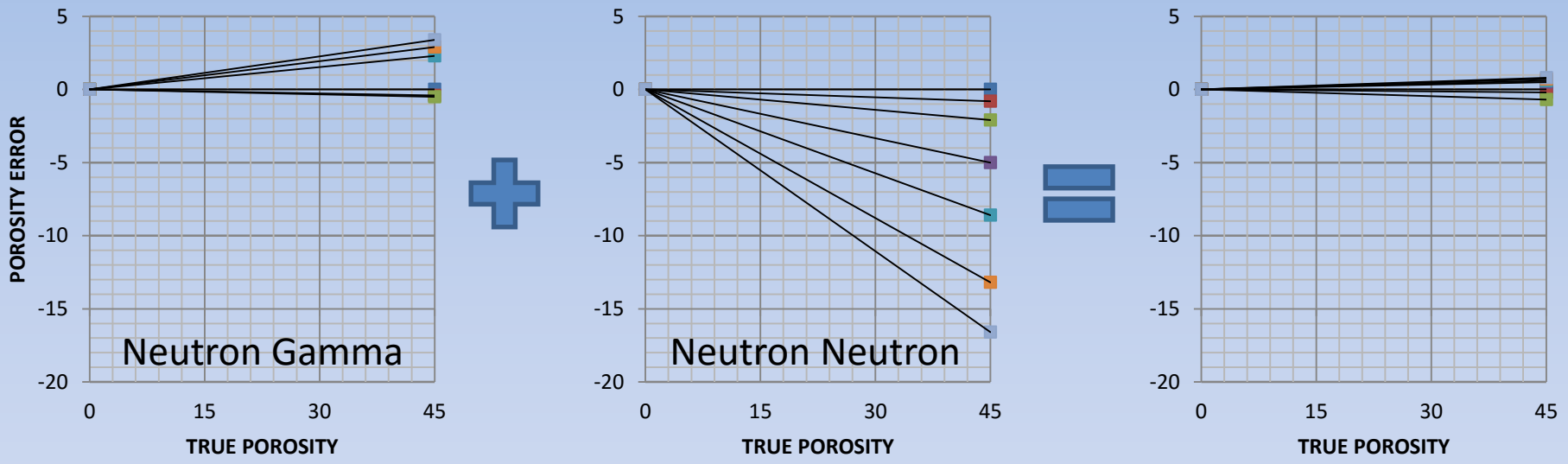
Liquid Porosity Error



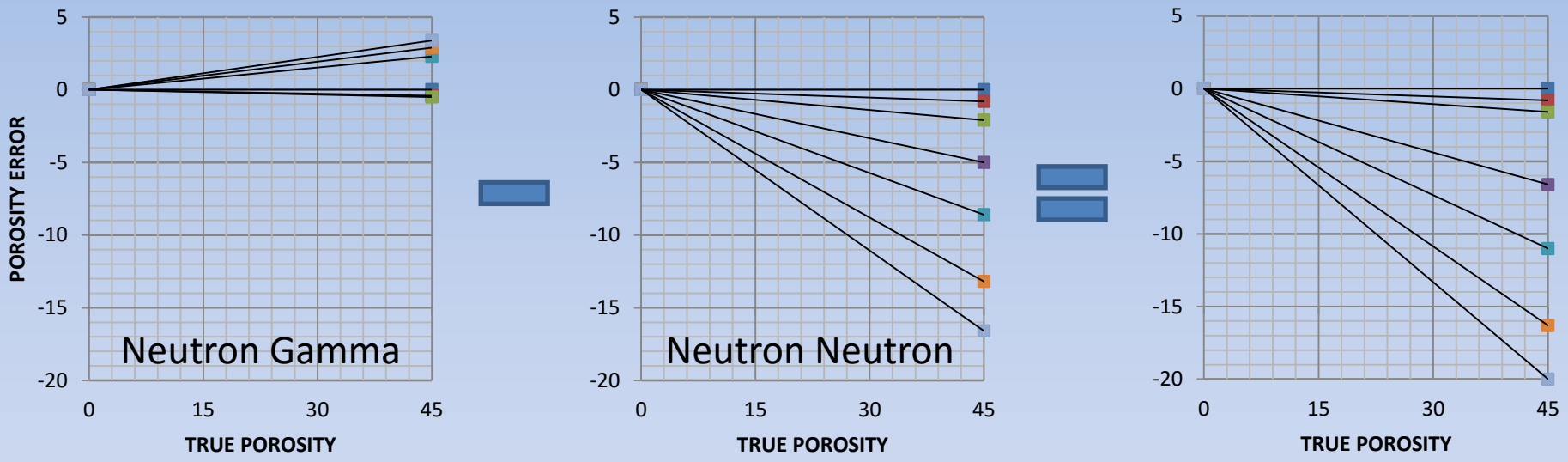


70 degree API oil
40 degree API oil
10 degree API oil
50 kppm NaCl water
100 kppm NaCl
200 kppm NaCl water
300 kppm NaCl water

Quad Total Porosity



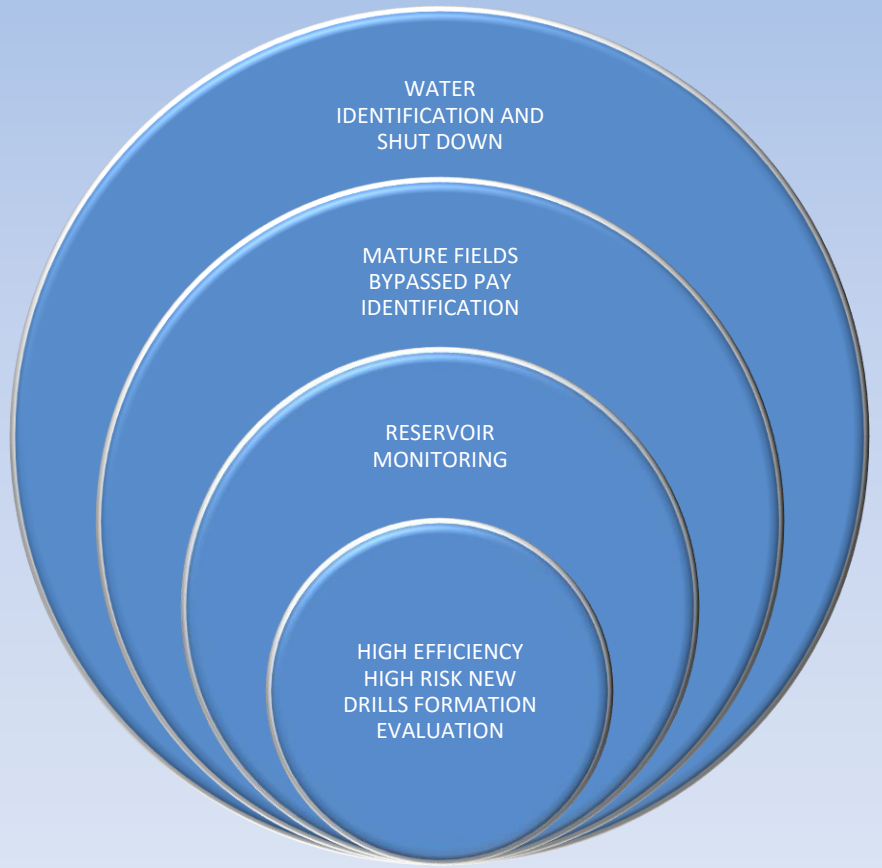
Quad Liquid Porosity



Problem solving

Solve multiple problems with a single technology.

QUAD NEUTRON

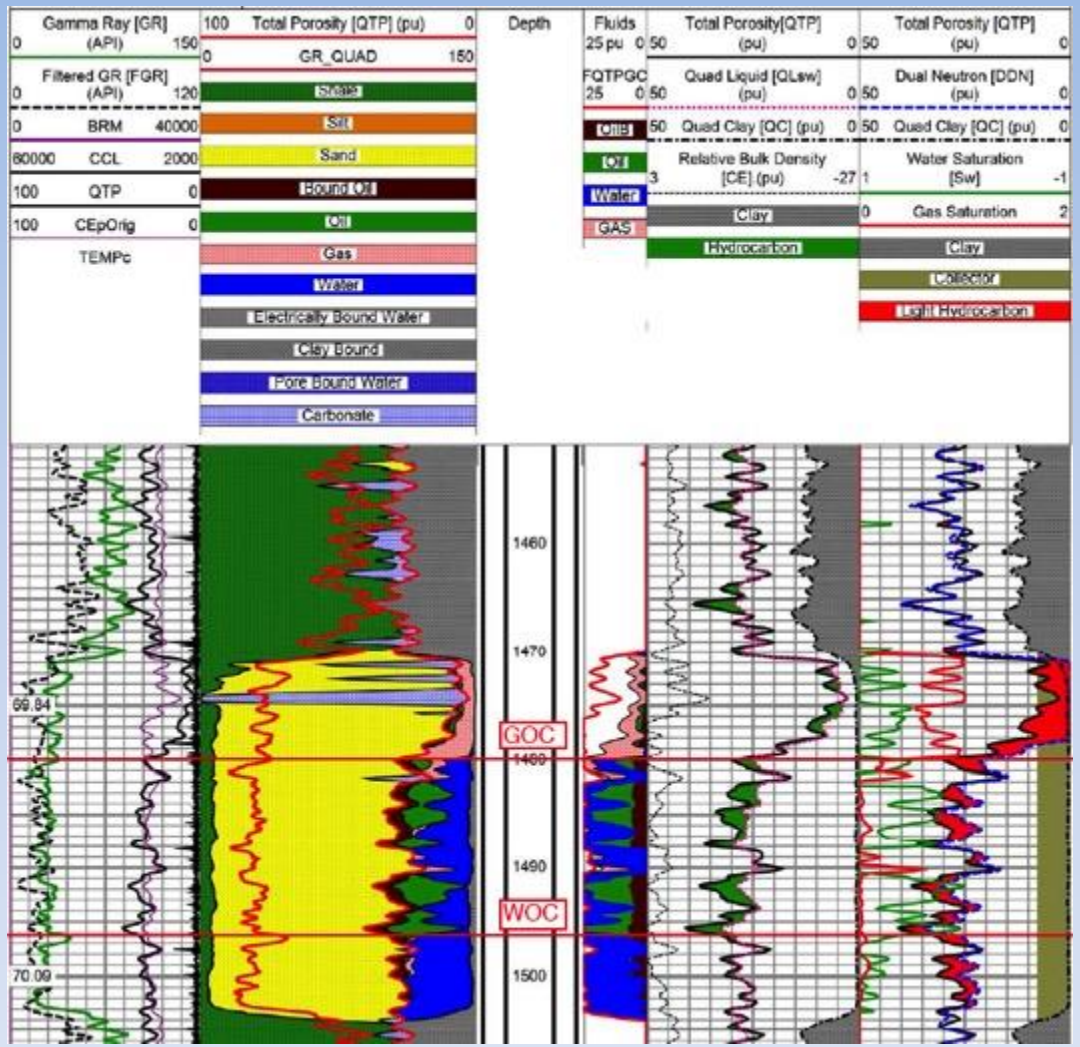


Problem Solving

- Obviously there are numerous other issues that contribute to the above mentioned segments and those we are addressing using QUAD
  - Fresh formation waters
  - Multiple casing/tubing strings
  - Drilling mud invasion
  - Cement invasion
  - Insufficient or missing OH data
  - High cost to conduct conventional logging
  - High risk deployment
  - Insufficient space on location
  - Etc.

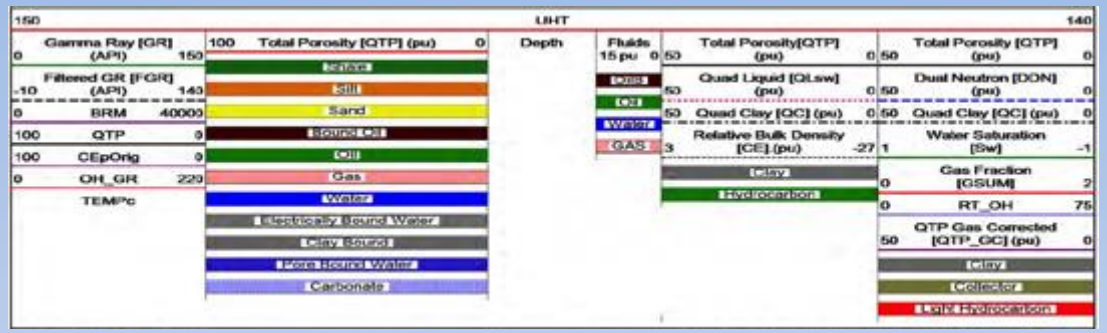
BYPASSED PAY

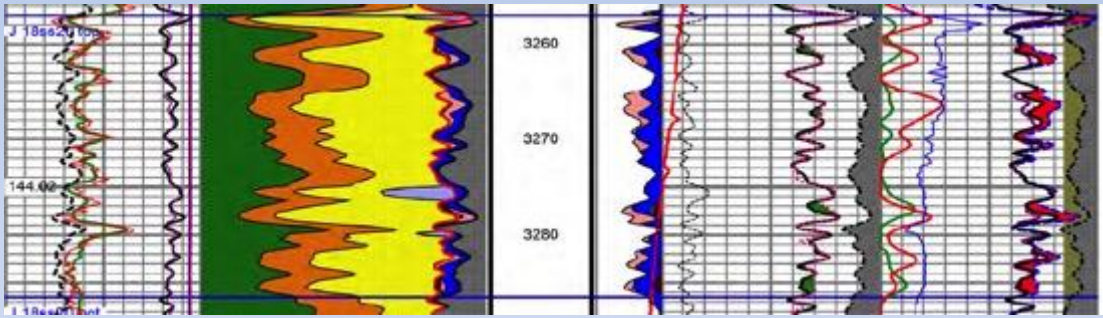
EAST MALAYSIA OIL WELL

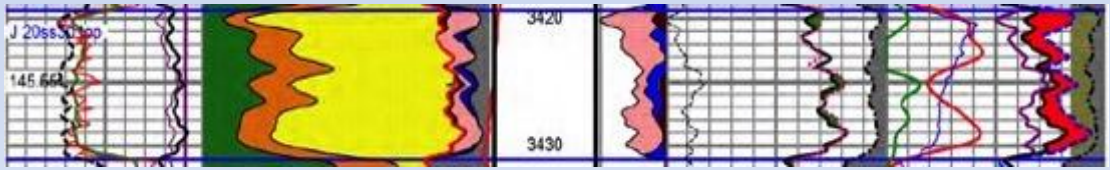


- Well in question is a Selective Single Oil Producer initially completed in May 2004
- In 2013 production went to water.
- After QUAD indicated interval was added and produces >500 bopd.

WEST MALAYSIA GAS WELL



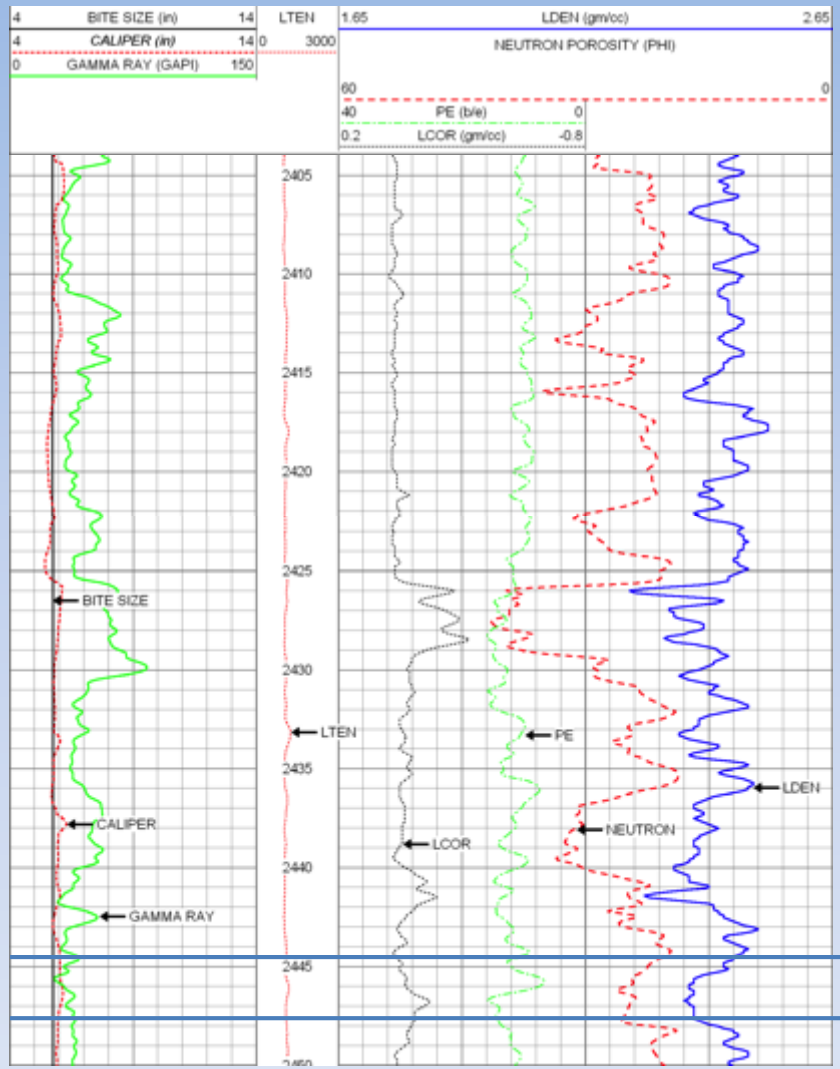


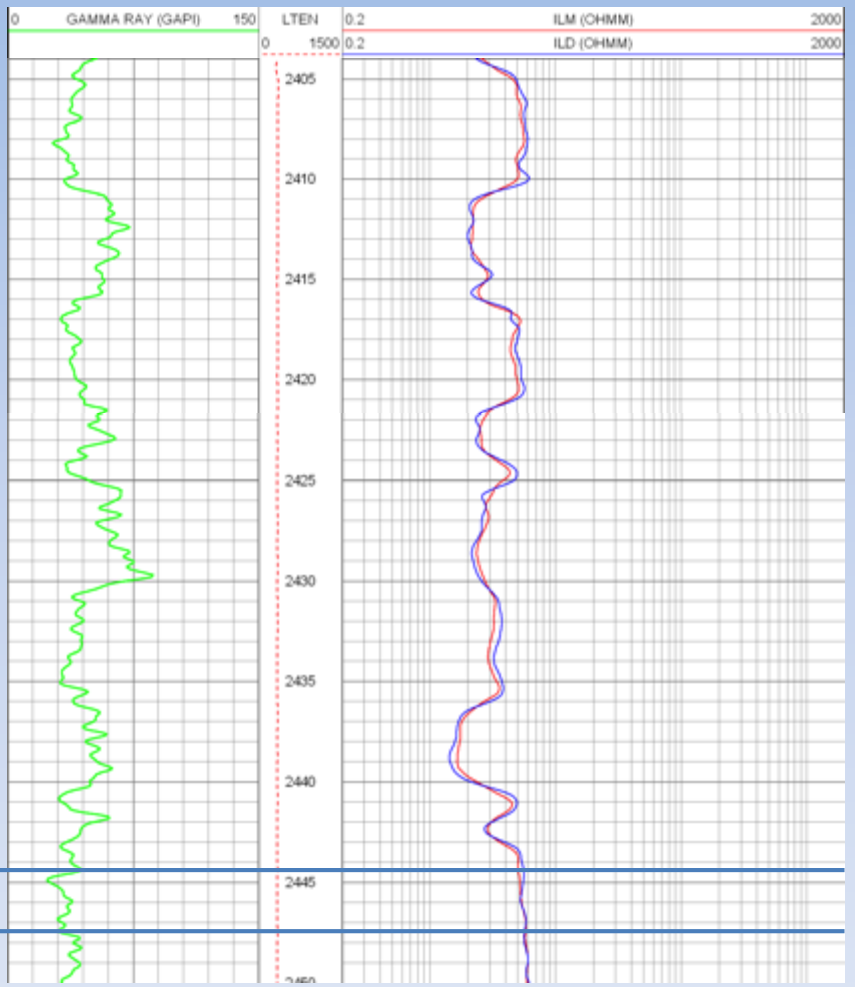


- Well went on production in 2010 and produced gas with continuous decline.
- Pre-logging job rate 11 MMscf.
- Upon completing upper interval well producing 41 MMscf.

FRESH FORMATION WATER ISSUES

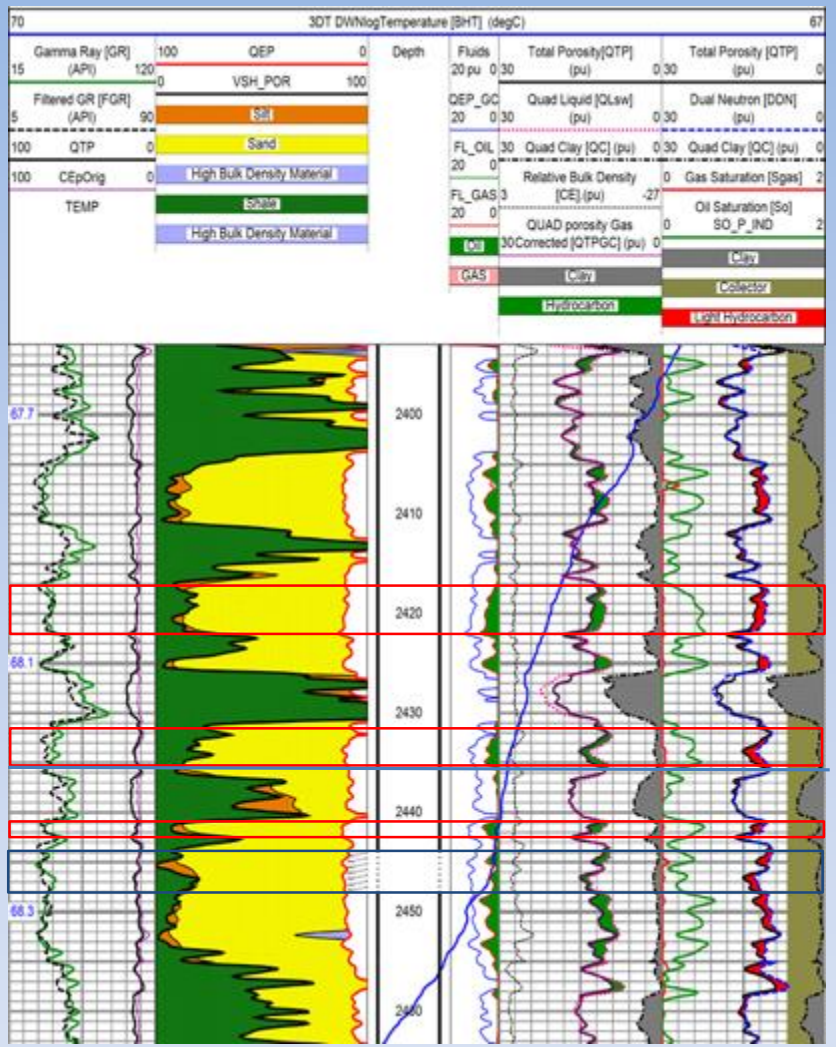
EXAMPLE OIL - AZB

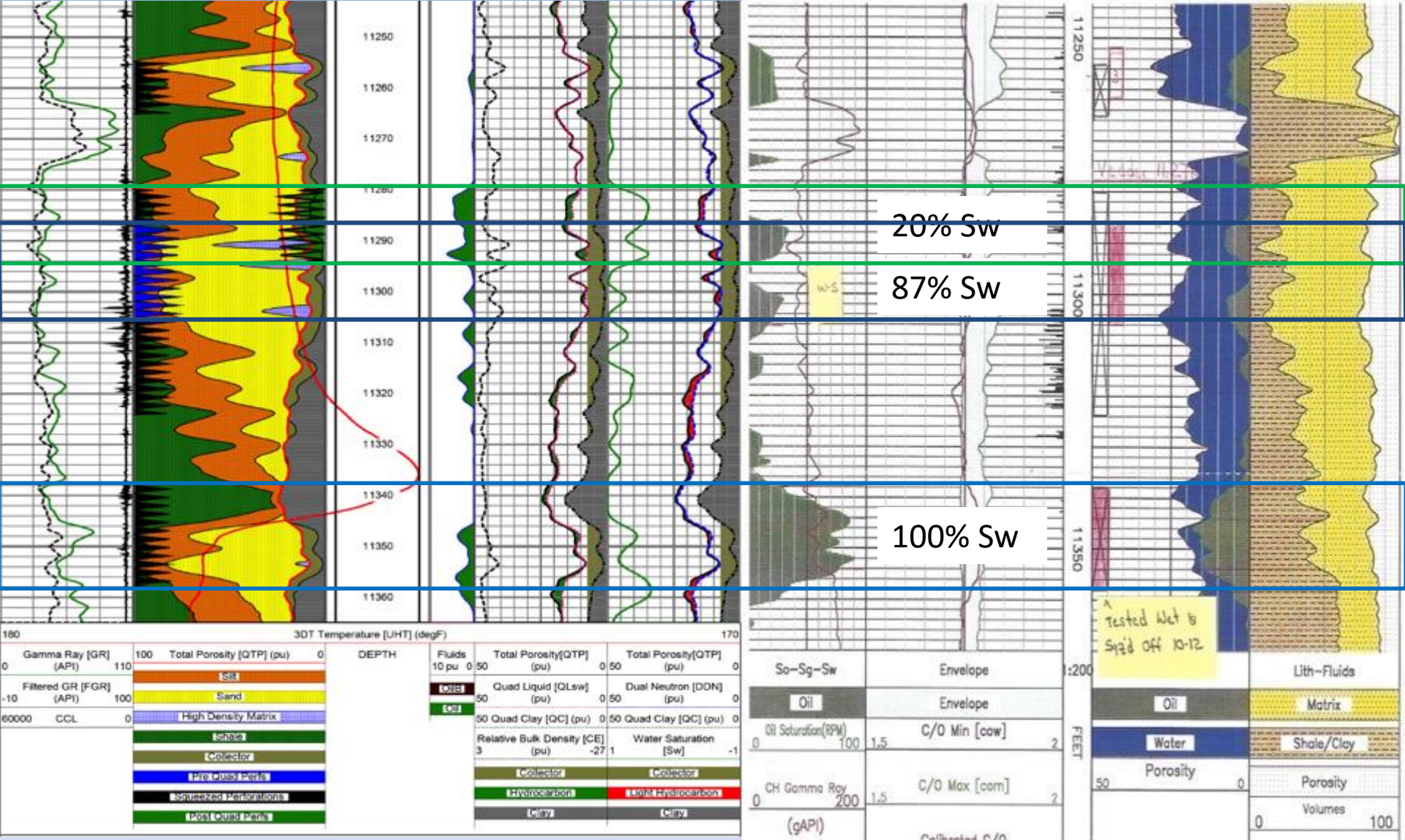




EXAMPLE OIL - AZB

1. The perforated interval had good perm but there is significant clay material present. No production possible. Most of HC are residual.
2. The interval from 2441 to 2444 m looks good with the best spot being at 2443 to 2444 m. Porosity is higher than perforated interval, the relative bulk density does not show it to be calcified and you have some clay traps for the oil.
3. Moving up the well, 2431.5 to 2435.0 m. Porosity is good, dual gammas are good, clay is low and relative bulk density is good. OWC at 2433.5 m.
4. Best possible interval 2417 to 2422 m. The dual gammas are excellent and the relative bulk density shows it to be light.



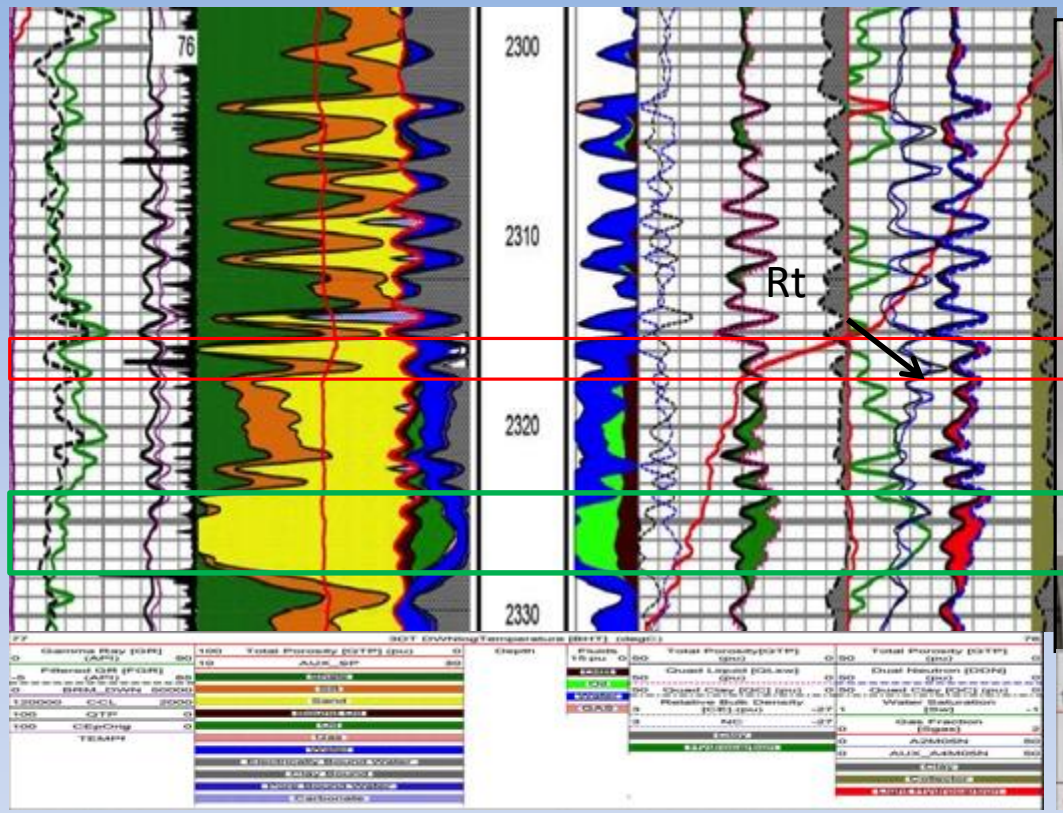


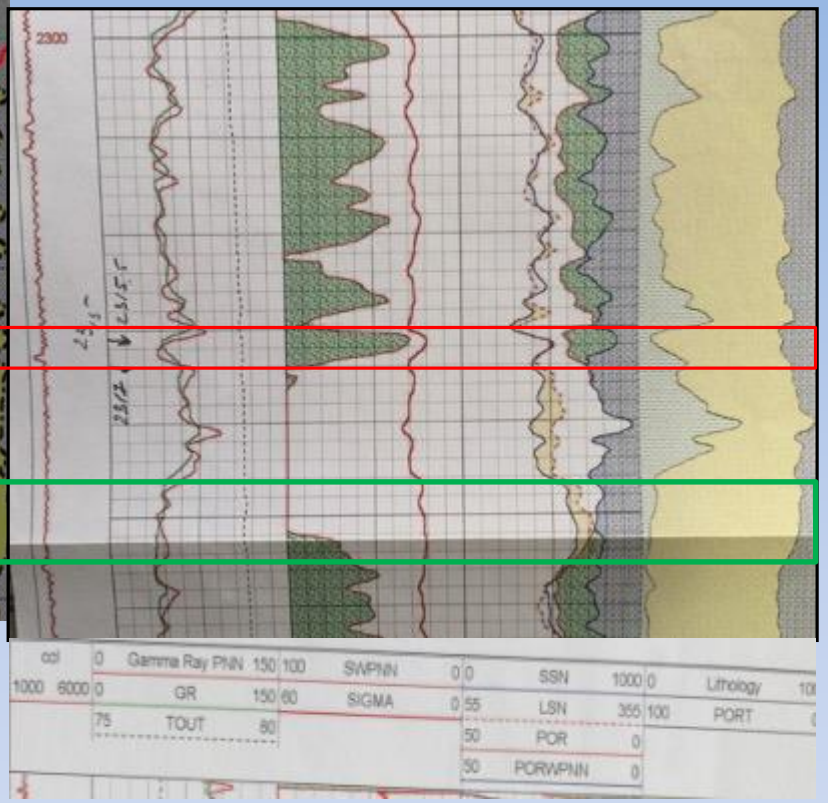
Before Quad: 40/260/36 (O/W/G)
After Quad: 124/5/110 (O/W/G)

Explanation for the previous slide

- Baker ran RPM log in CO mode. Identified 80% at bottom of sand. Customer perforated. 100% water production.
- Client had trouble squeezing it off because of the amount of water coming in but they did it. Customer then decided to shoot "blue" perfs based on offset wells. Well came in at 87% water cut. Produced 40 bopd and 200+ bwpd.
- After producing for a short period of time, the well went to 100% water cut (Customer believed that the lower squeeze let go and that is what killed the production).
- QUAD. They drilled out and re-squeezed lower interval and then we logged. Roke recommended that they shoot the upper interval, green colored perfs. They perforated and initial production came on at 20% water cut and stabilized to 4% water cut producing 125 bopd and 5 bwpd

ZYKH - AZB

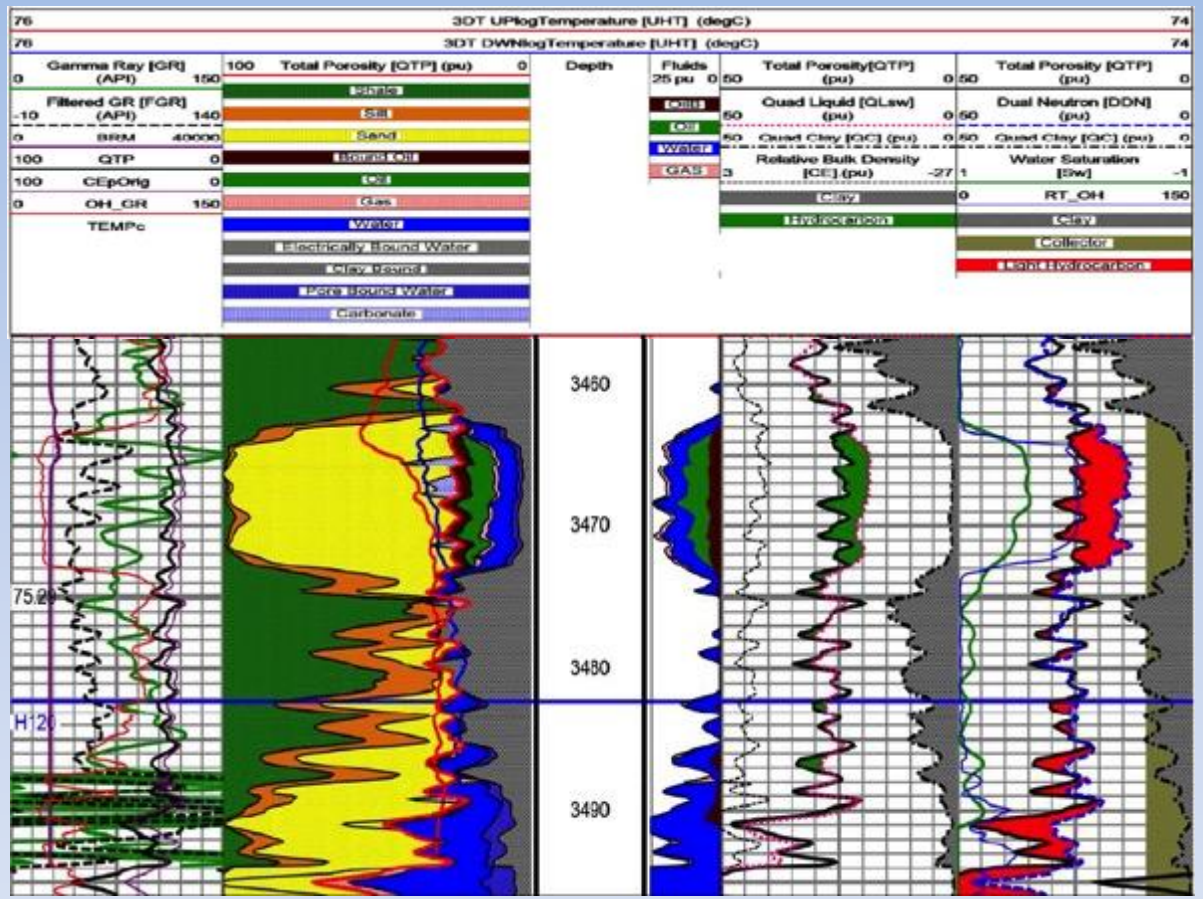




Based on OH and PN data well was perforated in the interval 2315.5-2317m Well produced 480m3 water. This well was shut down for about 1 year. Then decision was made to do WO. QUAD was run and identified new pay zone 2324-2328m. That zone was perforated but unfortunately upper existing water saturated zone is not isolated due to technical issues. Production after perforation 3m3 oil and 480 m3 water.

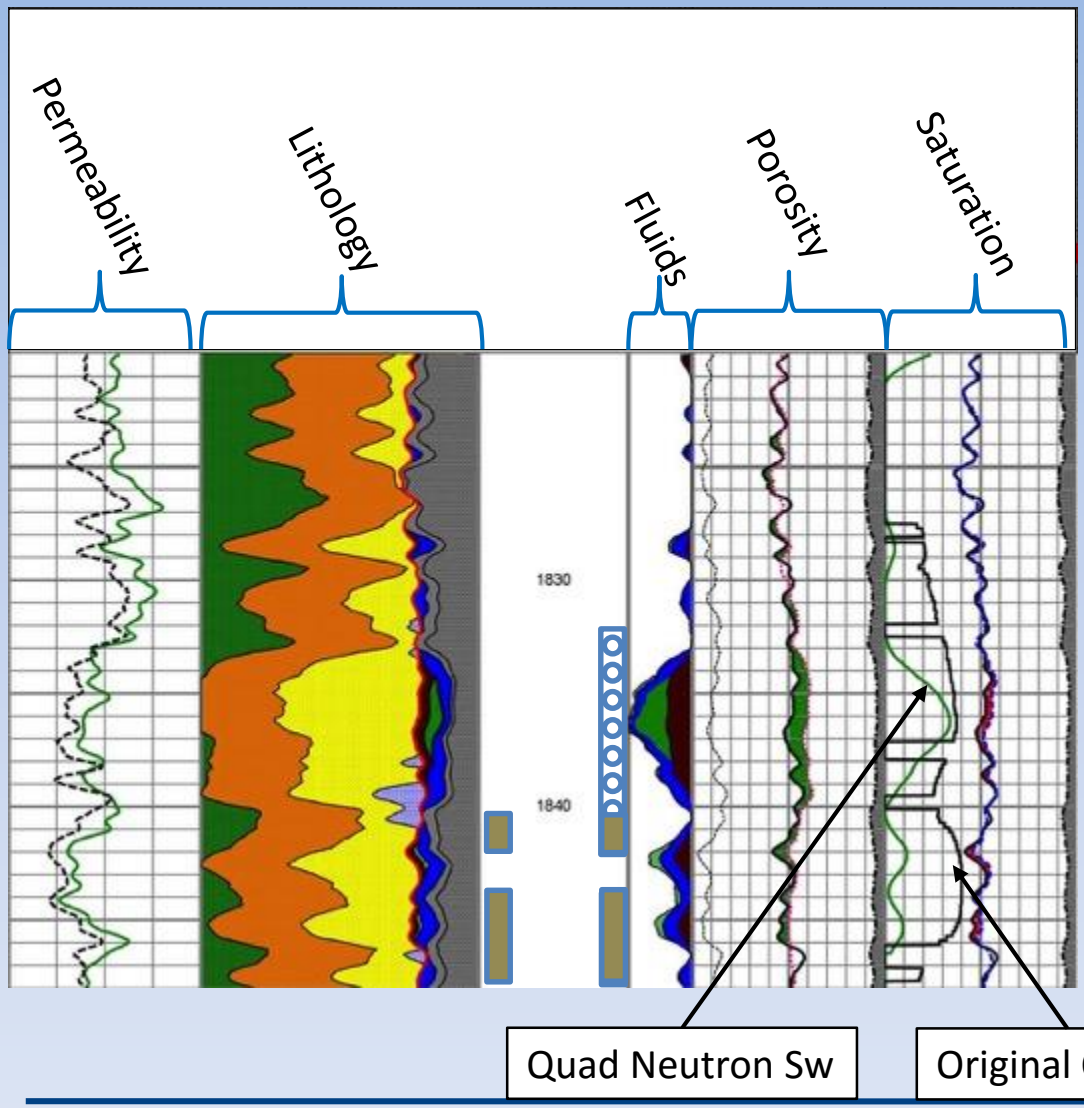
WATER SHUT-OFF

EAST MALAYSIA OIL WELL – WATER SHUTOFF



- Well is a highly deviated oil producer completed with gravel pack and screen. Went on production in 2012.
- In 2013 water broke through and water cut exceeded 96% .
- Upon completing logging job and setting plug as recommended by ROKE water cut went down to 40%.
- Well now producing in excess of 1000 bopd.

EXAMPLE WATER SHUT OFF - RUSSIA



Shaly Sand Formation
OH 1980's / Quad 2012
25 API Oil/8k ppm Water

Pre-Intervention Production
- 277 t/day total fluid
- 7.4 t/day oil
- 97% Water Cut

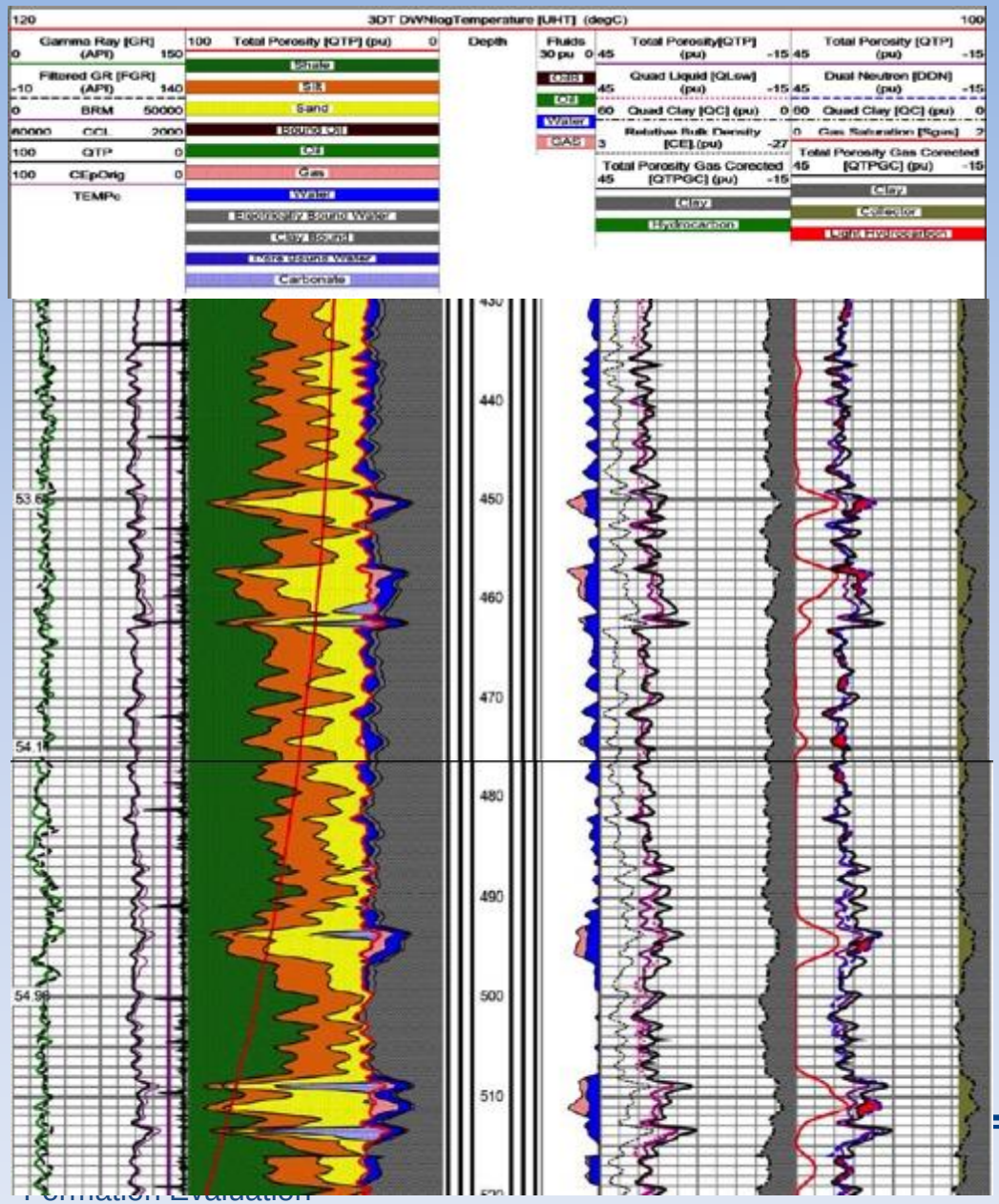
Cement Squeeze Intervention

Post intervention Production
- 25 t/day total fluid
- 11.0 t/day oil
- 44% Water Cut

91% ↓ Water
49% ↑ Oil

MULTIPLE TUBULARS

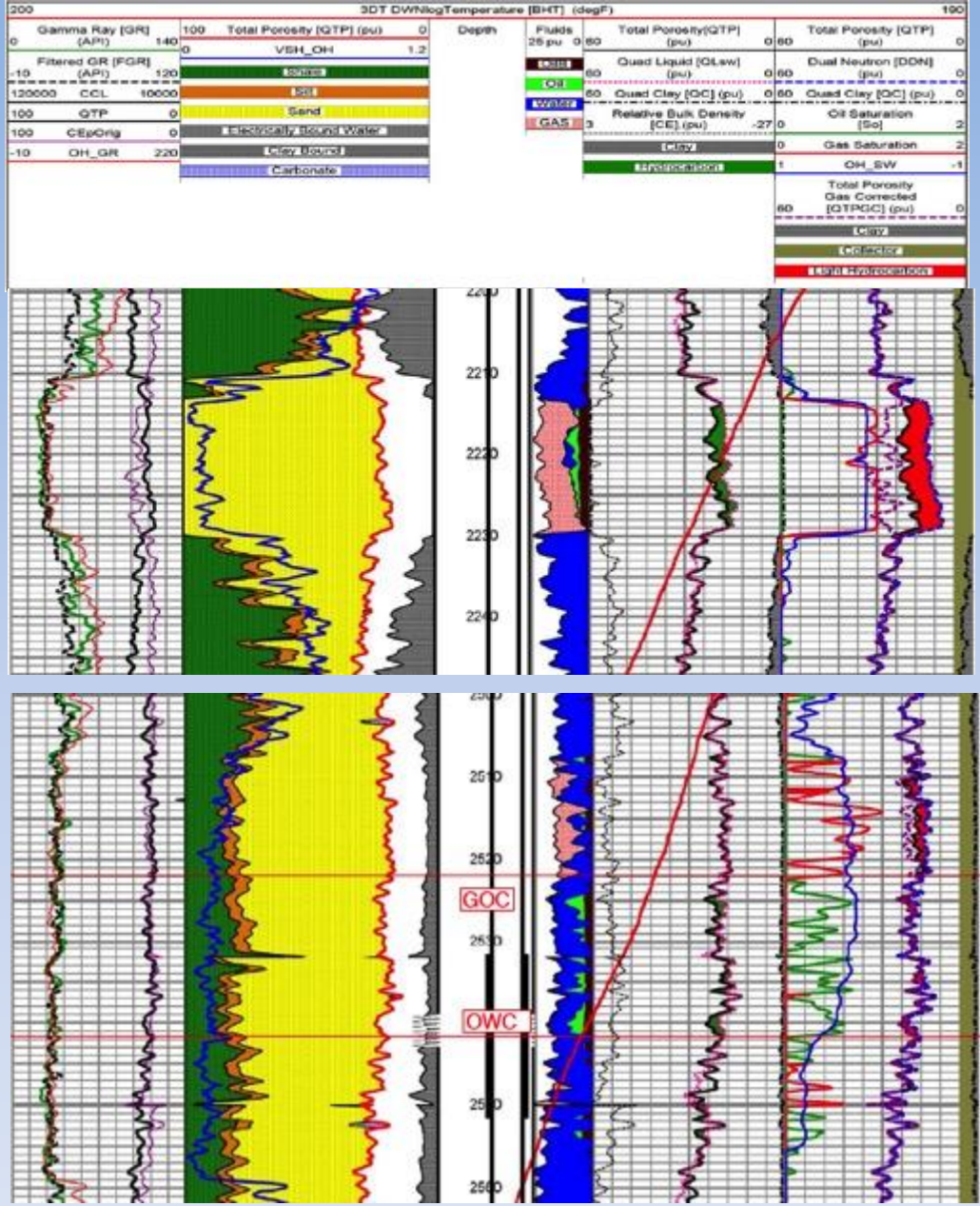
WEST MALAYSIA GAS



- Well logged in April 2014 through
- 3 string of Casing and 1 Tubing
- Logging job objective is to identify Shallow gas intervals behind casing

Roke Technologies Ltd.

WEST MALAYSIA OIL/GAS



- Well logged in October 2015 through Long string of Dual-Tubing and Casing
- Logging job objective is to identify Oil and Gas contacts behind casing

CARBONATES

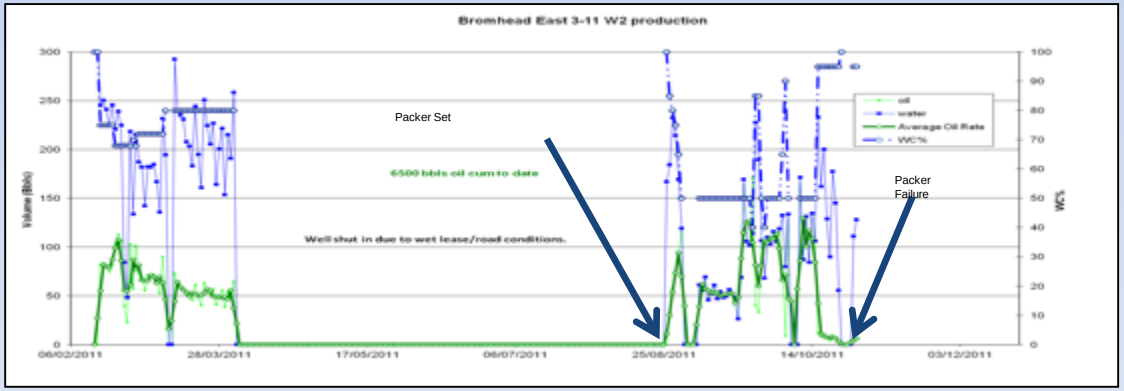
South East Saskatchewan Platform Carbonate
Water Identification and Shut Off

Porosity below zero is anhydrite well path out of zone

Green shading identifies oil

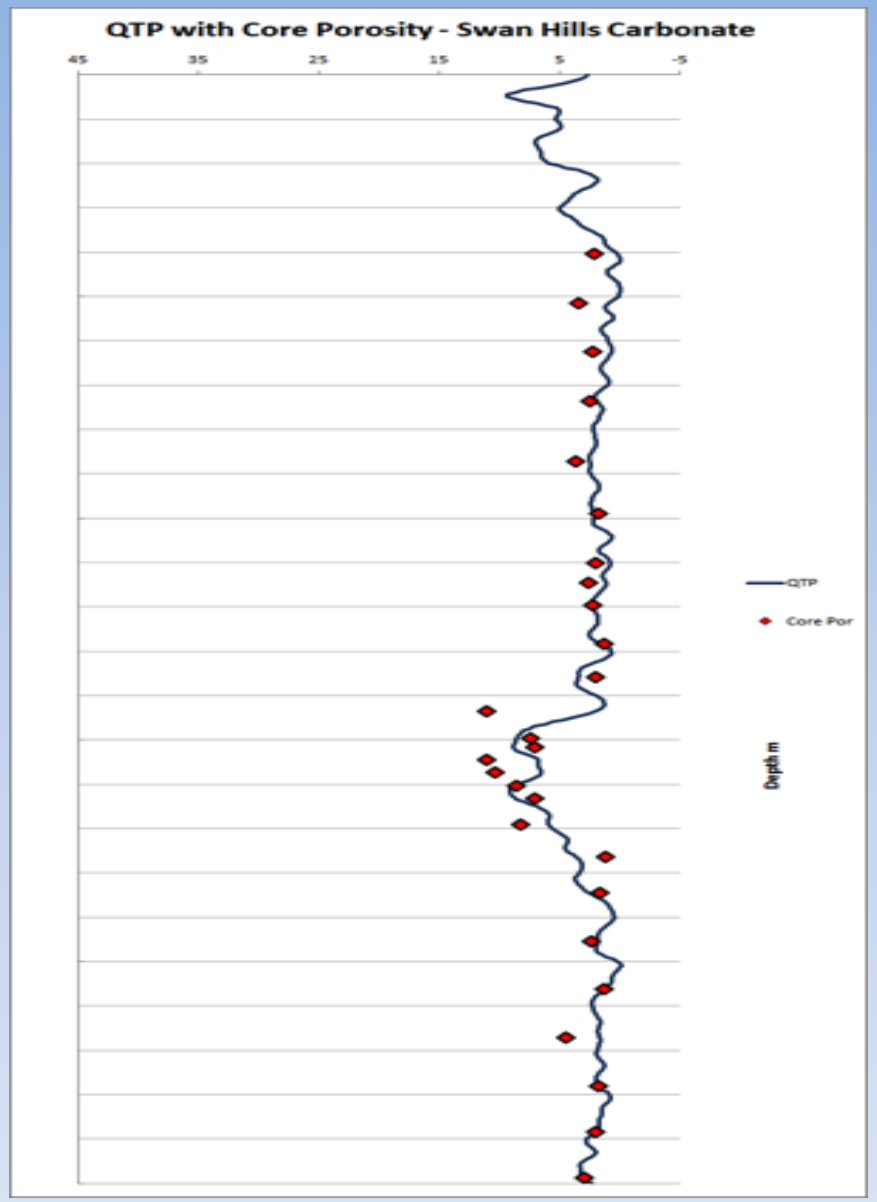
No green shading indicates water

Placed packer to isolate poor reservoir



Explanation for previous slide

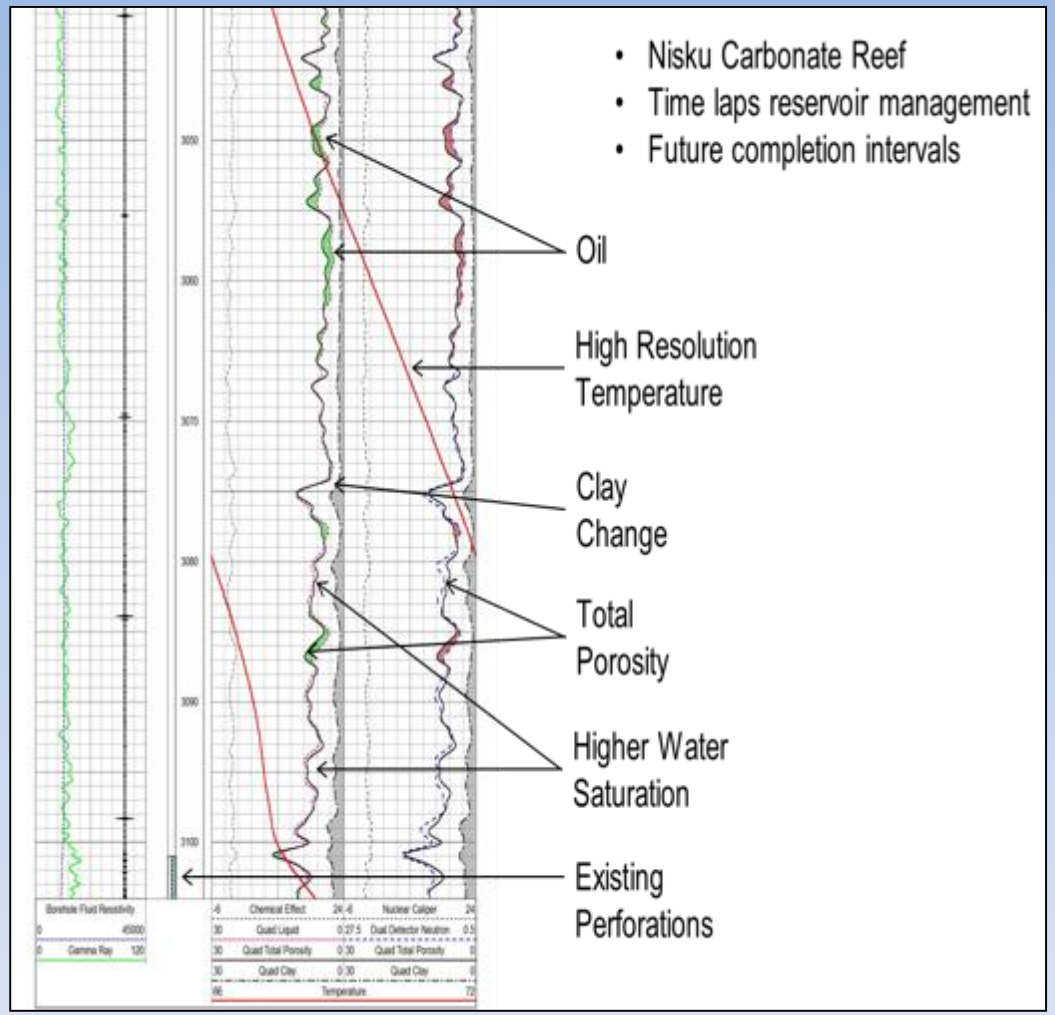
- Well is located in the SE part of Saskatchewan province, Canada.
- Well was wild-cat – no seismic, no logging initially. Based on the cuttings everything looked rather negative.
- Owner had to make decision – P&A or log it. Roke was selected for logging. Based on Roke data oil was indicated close to the intermediate casing shoe..
- Client noted that if they get 6 bopd – they'd be happy. They received over 100 bopd – see production chart below the log.
- Unfortunately they had packer failure and got some serious water cut afterwards. No production data available after WO operation.



Quad vs. Core Porosity

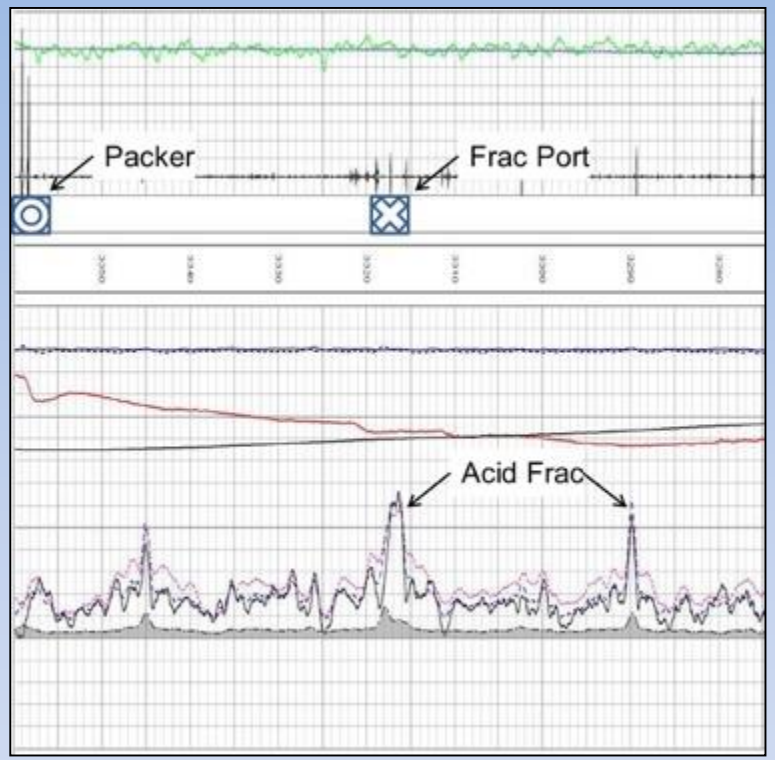
- Core derived Porosity – red dots
- Blue curve – QUAD QTP – total porosity
- Swan Hills is carbonate with inter-crystalline porosity at 3-6%

Nisku Reef - Vertical Well



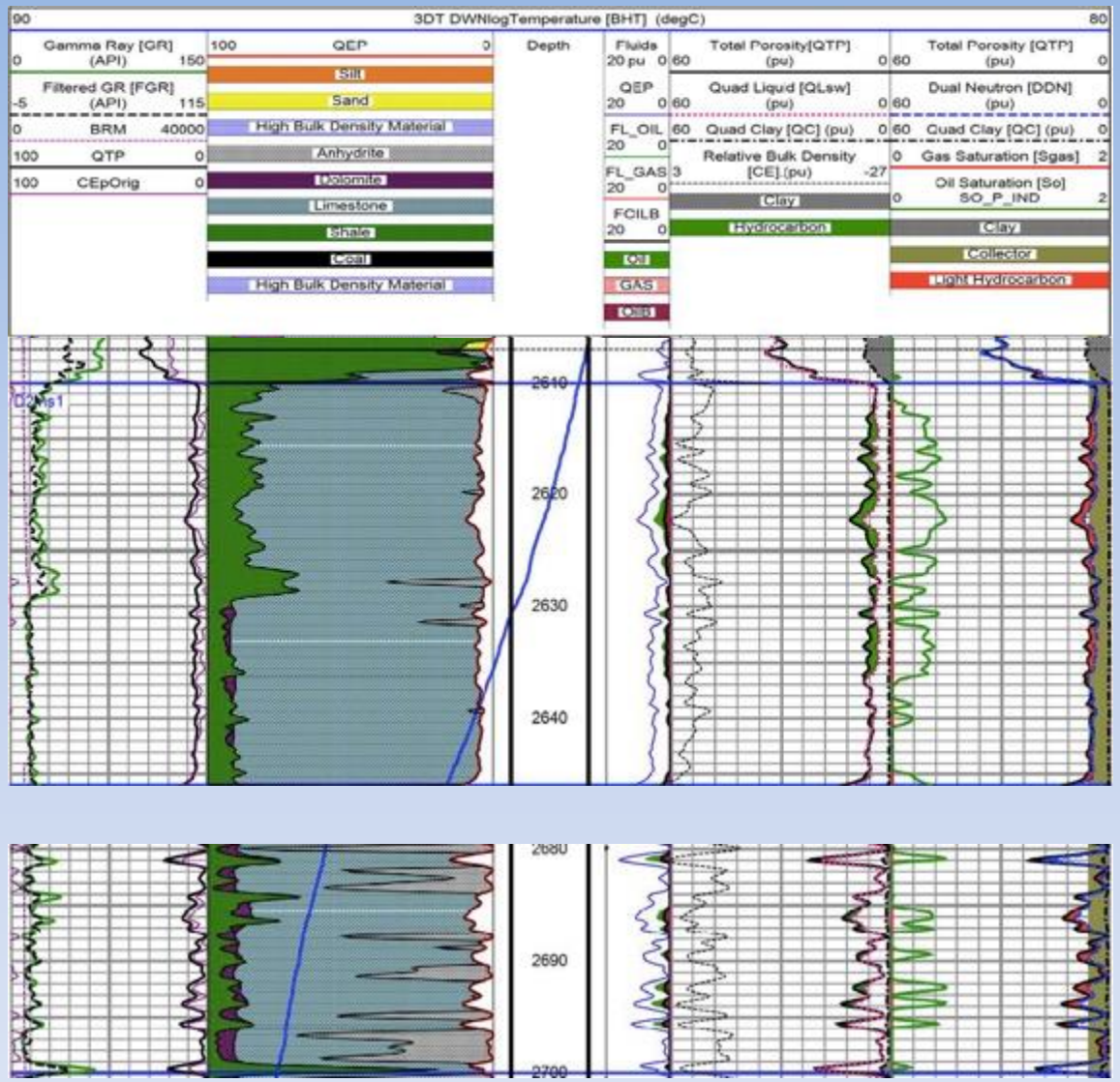
- This particular reef deposit is characterized by the presence of the high pressure Oil Pockets.
- Well was drilled in mid-90s and for the pressure maintenance water injection followed by gas-solution and then dry gas injection was used.
- On log displayed oil pockets missed during initial completion Log completed through casing in 2012.

Swan Hills Platform Carbonate Acid Fracture Examples



- This is an acid job example where QAUD was used to identify acid entry zones.
- These are marked with arrows on the pictures.

EXAMPLE RUSSIA



- Well logged in April 2016 through casing.
- Based in QUAD log 12-15 bopd was obtained from different intervals prior to treatment.
- After treatment production increased to ~50 bopd.

DRILLING APPLICATIONS

Open Hole Alternative

Conventional Open Hole

- Lithology
  - Natural Gamma Ray & PE
- Porosity
  - Neutron
  - Density
    - Introduced gamma
- Saturation
  - Resistivity
  - Archie's Sw Equation
- Permeability indicator
  - Spontaneous Potential

Quad Neutron (Thru Pipe)

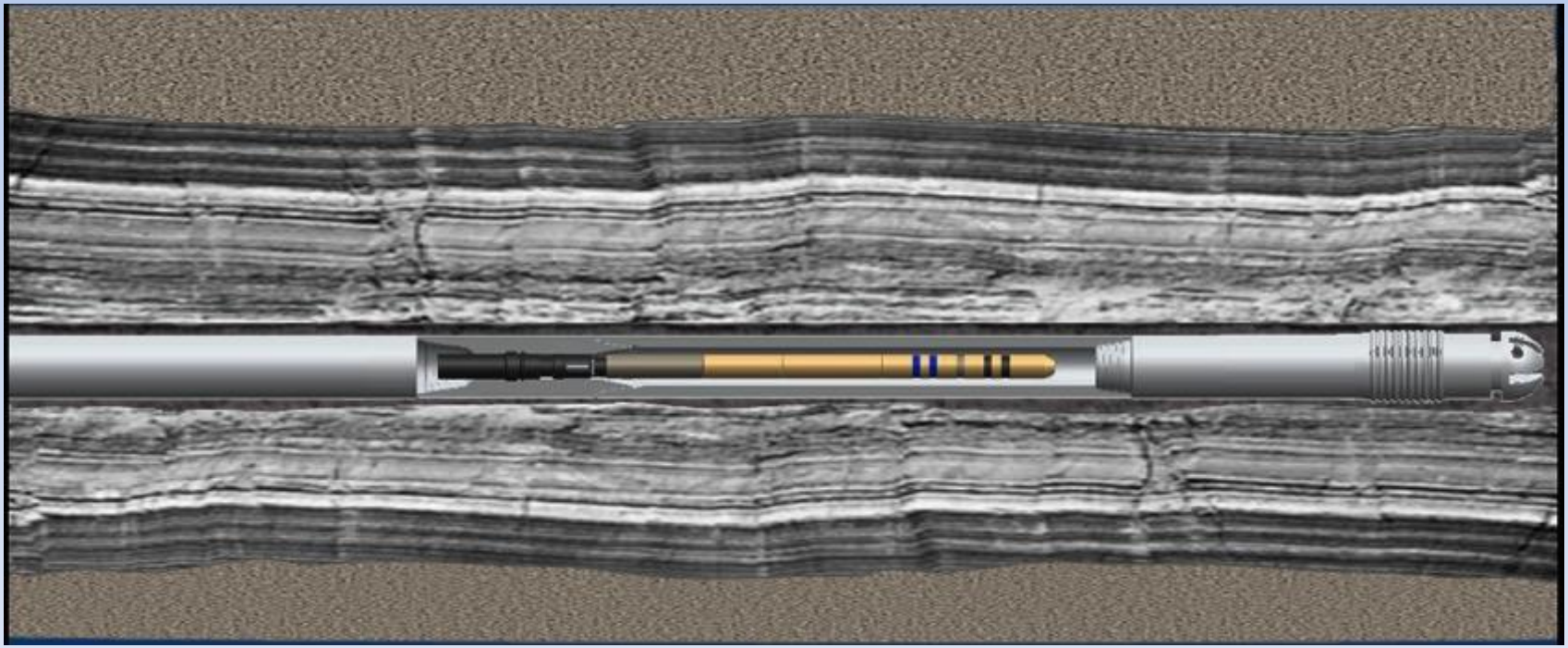
- Lithology
  - Natural GR & Quad Clay
- Porosity
  - Neutron
  - Density
    - Induced gamma
- Saturation
  - Quad Liquid
  - Roke's Sw Equation
- Permeability indicator
  - Proprietary Dual Gamma

Open Hole Alternative Applications

- Excellent alternative when open hole data is difficult to acquire
  - High risk horizontal new drills
  - Unconsolidated / unstable formations
  - SAGD wells
  - Ultra-small diameter sidtracks
  - **Solution**
    - Log thru drill pipe
    - Case and then log
- Excellent supplemental data when production does not agree with open hole expectations
  - Wells with cement and drilling mud damage
  - **Solution**
    - Log thru tubing/casing
- Excellent formation evaluation data when open data does not exist or is of poor quality
  - Older mature field wells
  - New wells with questionable open hole data
  - **Solution**
    - Log thru tubing / casing

LWR and PUMPDOWN

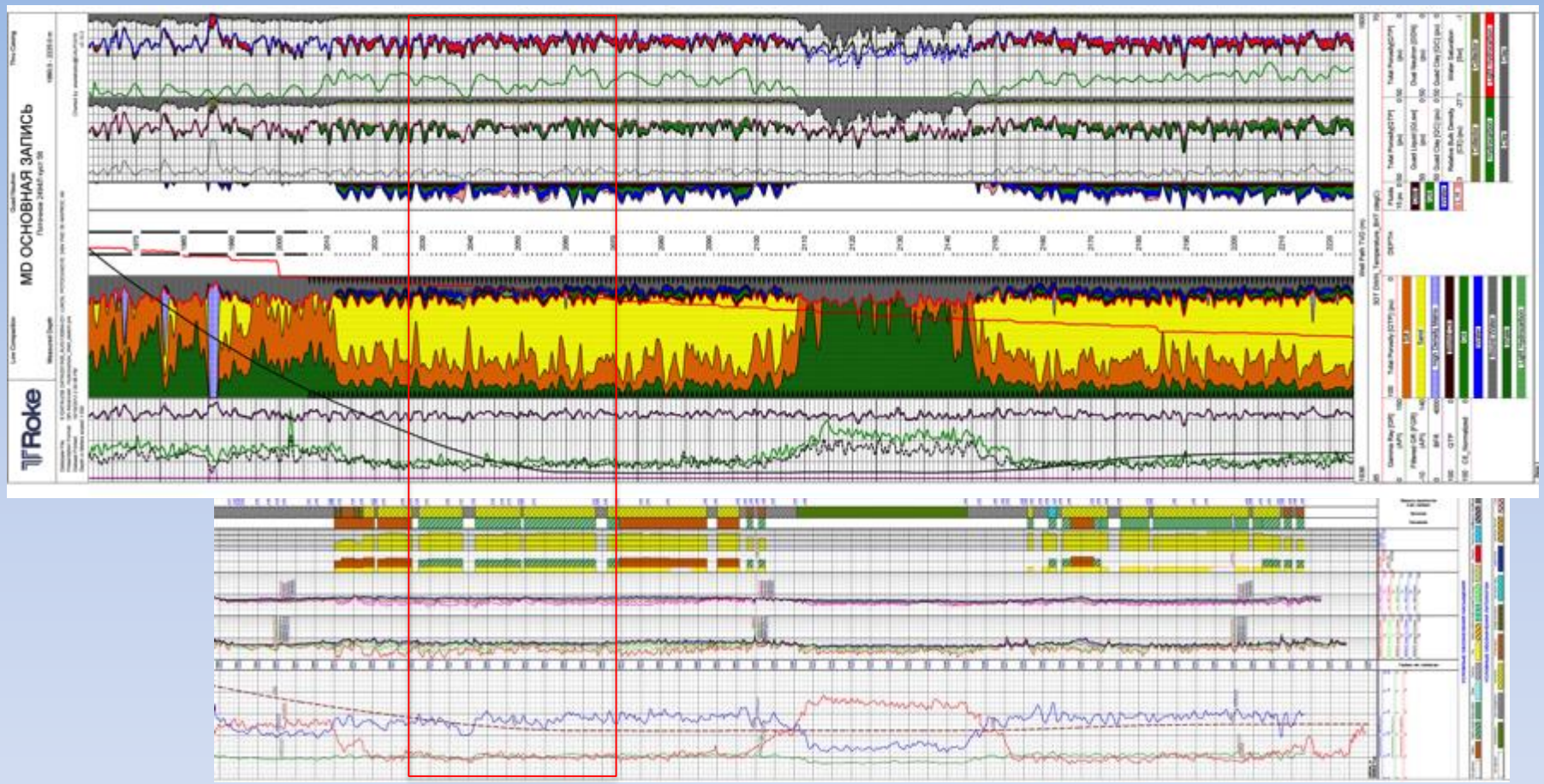
- Low Risk, Cost Effective
- Faster than PCL or Well Shuttle
- Highest first run success
- Full well control with circulation, rotation & reciprocation



Russia OH application

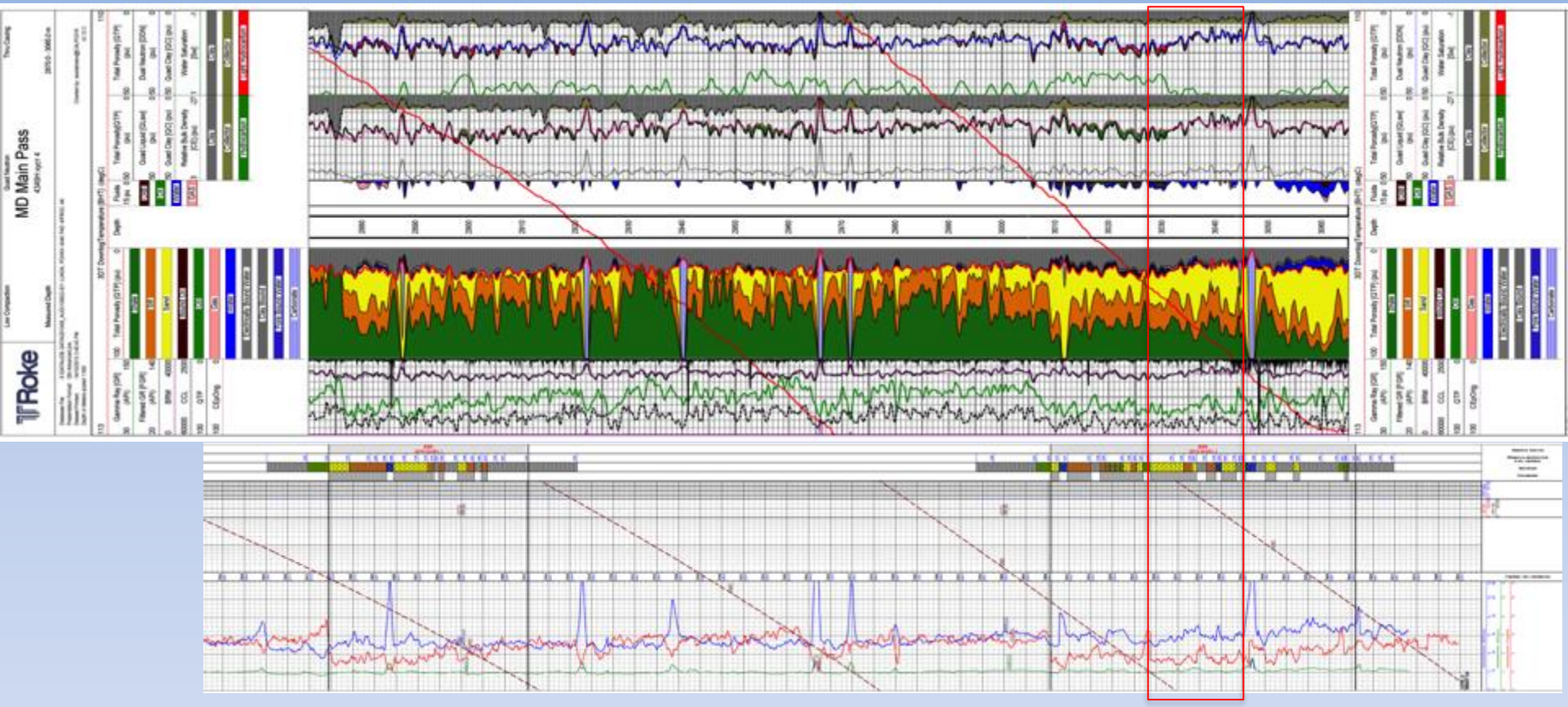
- To date completed over 50 wells – horizontal sidetracks and new wells in KOMI and Western Siberia regions.
- Replaced basic OH logging to:
  - Reduce risk of loosing tools
  - Provide higher resolution measurements
  - Identify tight and water/oil bearing strata
  - Serve as primary petrophysical data for reserve evaluation
  - Save significant amount of rig time

Well 1 - Russia



Horizontal sidetrack
Based on OH data (lower picture) zone 2025 – 2070 completely wet.
Based on QUAD data we can see Oil and Water bearing zones within the same interval. Confirmed by production

Well 2 - Russia

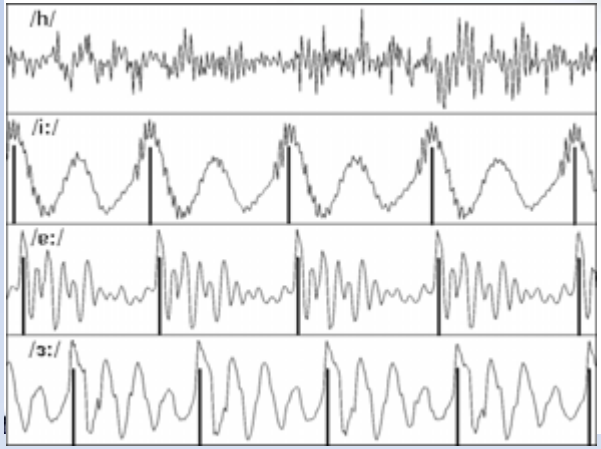


Horizontal sidetrack.
Well cased, perforated and fraced in the interval 3027-3045
After Perforation watercut 70%
QUAD recorded after Frac job to identify remedial work. Clearly seen that perf job was done in water-bearing section
After QUAD plug was set and reperforation done. Current Oil production 44t/day with watercut 23%

QUAD LEAK DETECTION

Sound Hound™

- Roke's proprietary ventflow gas source location device
- Multi Sensor full wave acoustic
- Slim Design, Wireline or SL Deployable



QLD – QUAD leak Detection

Tool Diagram	Description	OD (mm)	Length (m)	Weight (kg)
	Battery Sub	43.00	1.22	8.00
	Noise Sensor	43.00	3.17	19.60
	Battery Sub	43.00	1.22	8.00
	Quad Memory Sub	43.00	1.37	12.00
	TCA	43.00	1.97	20.00
	MNA	43.00	2.13	20.00
	Bottom Hole Temperature	43.00	0.45	5.00

Total Length = 11.53 m
Total Weight = 92.60 kg

- Another application of Quad technology is QUAD Leak Detection.
- Why is it better and How is it different from any other Leak Detection devices on the market?

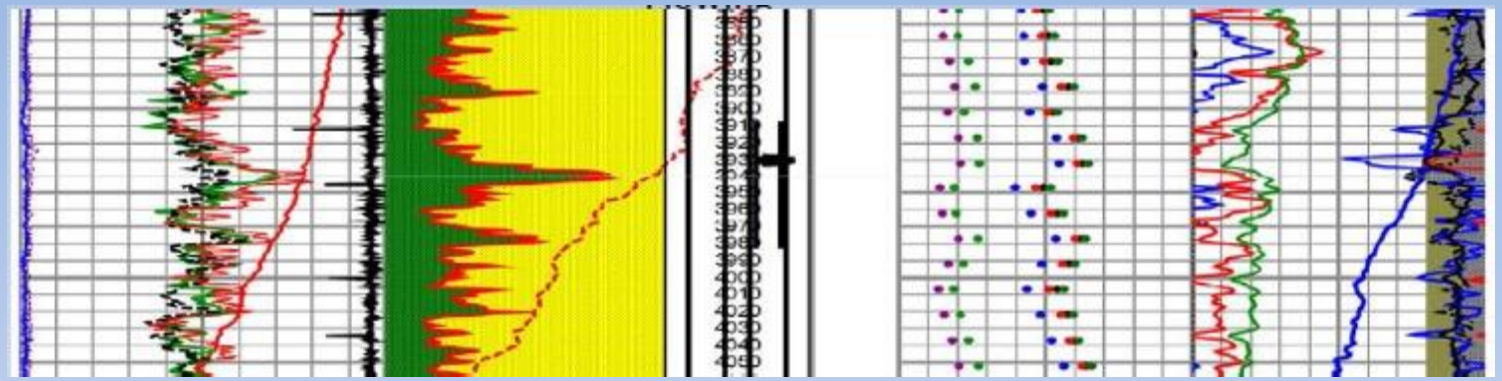
Roke Technologies Ltd.

QLD difference and benefits

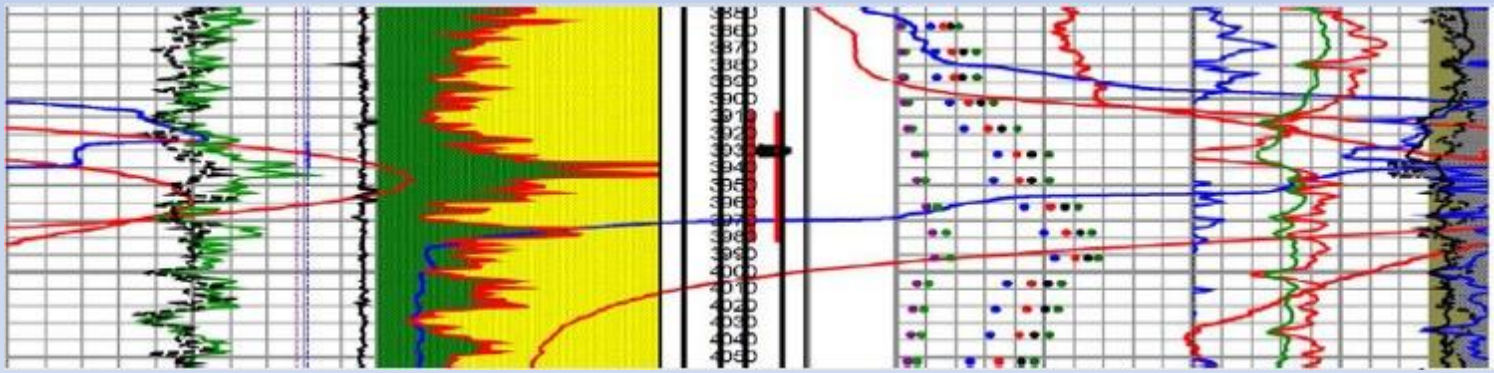
- Primary difference from all other devices on the market is the ability to provide significantly more information than any other device.
- From Noise portion of the tool we can obtain all necessary sound information, digitize it downhole and download on surface.
- From QUAD portion we can obtain all necessary information about fluids around the tool in tubing or in annulus
- Another major advantage is ability to run this service in memory mode which allows for significantly less expensive deployment.

QLD Example

Flowing pass



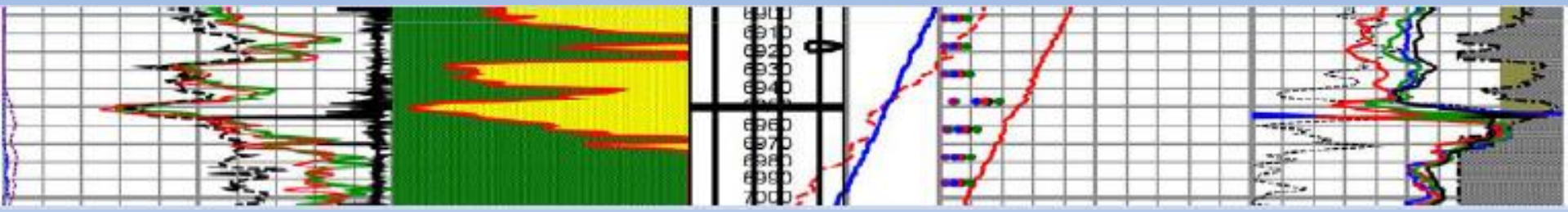
Shut-in pass



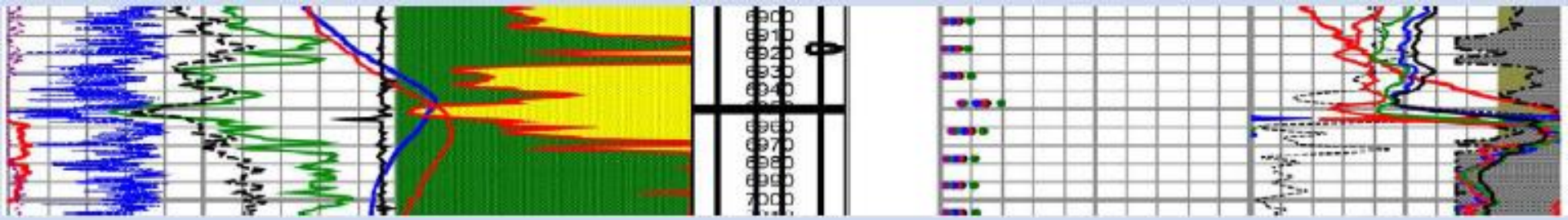
- 3,920-3,950 – LS tubing leak
  - Significant temperature & noise response during shut-in pass – indicative of LS leak (straddle not holding)

QLD Example

Flowing pass



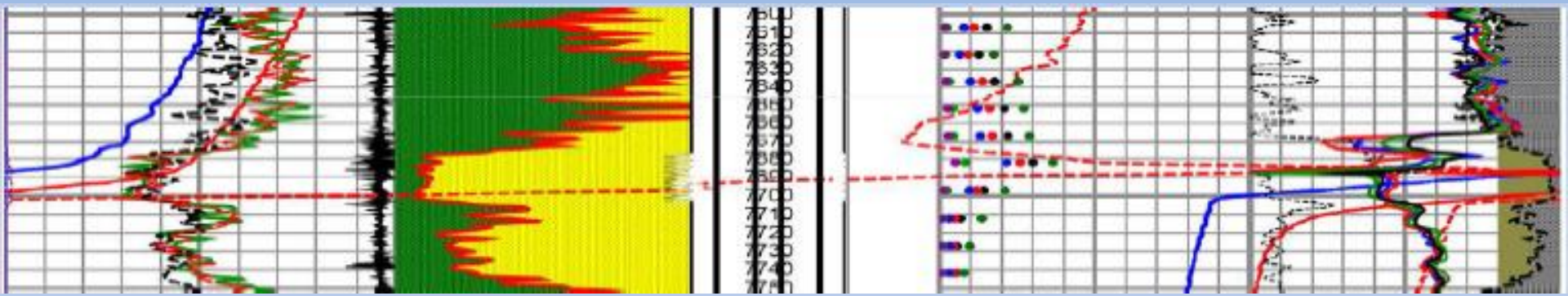
Shut-in pass



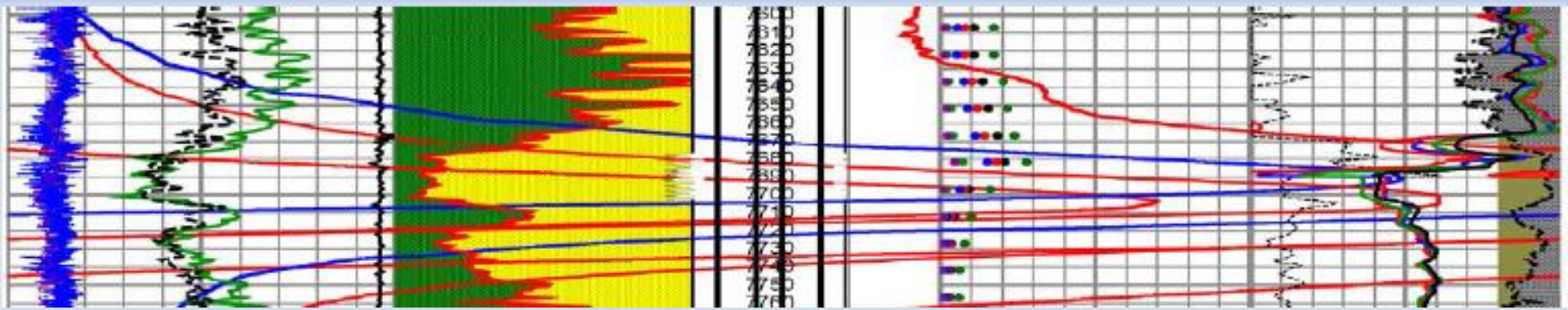
- 6,950 – packer leak
  - Drop in temperature response
  - Increase in noise plot
  - QUAD responses indicates there is gas trapped below packer & we see liquid above packer

QLD Example

Flowing pass



Shut-in pass



- 7,680 – 7,700 – LS & tubing leak
  - Noise and temperature changes in both flowing & shut-in conditions.
  - QUAD response showing annulus fluid level @ 7,690ft

GLOBAL APPLICATION STATS

LOCATION	OIL/GAS	DEPTH (FT/M)	DEVIATION	OBJECTIVE	RESERVOIR TYPE	BEFORE USING QUAD	AFTER USING QUAD
EAST MALAYSIA	OIL	1450-1700 M	74 DEG	OBC	SANDSTONE	100% WATER	500 BOPD
EAST MALAYSIA	OIL	3100-3500 M	83 DEG	WS	SANDSTONE	96% WATER	1000 POPD, 40% WATER
WEST MALAYSIA	OIL/GAS	2300-2400 M	84 DEG	Model Conf	SANDSTONE	2400 BOPD 40% WATER	3934 POBD, 26% WATER
WEST MALAYSIA	GAS	3200-3550 M	60 DEG	OBC	SANDSTONE	11 MMSCF	41 MMSCF
WEST MALAYSIA	GAS	2500-2900 M	72 DEG	OBC	SANDSTONE	9 MMSCF	35 MMSCF
RUSSIA	OIL	2300-3100 M	HORIZ	HRD	SANDSTONE	25 POPD, 79% WATER	320 BOPD, 24% WATER
RUSSIA	OIL	2600-3200 M	HORIZ	HRD	SANDSTONE	100% WATER	280 BOPD, 21% WATER
RUSSIA	OIL	2000-2700 M	VERTICAL	WS	SANDSTONE	96% WATER	120 BOPD, 41% WATER
RUSSIA	OIL	2200-3100 M	VERTICAL	UNCON	SHALE	USED FRACKING	FLOW W/O FRAC
AZERBAIJAN	OIL	2000-2500 M	VERTICAL	WS	SANDSTONE	100% WATER	120 BOPD, 35% WATER
AZERBAIJAN	OIL	3500-4100 M	45 DEG	OBC	SANDSTONE	NO PRODUCTION - OLD	100 BOPD, 15% WATER
AZERBAIJAN	OIL	2700-3500 M	VERTICAL	OBC	SANDSTONE	NO PRODUCTION - OLD	140 BOPD, 20% WATER
CANADA	OIL	500-1000 M	HORIZ	WATER	TAR SANDS	IDENTIFY WATER	SUCCESS ISOLATION
CANADA	OIL	2250-3700 M	75 DEG	HRD	SANDSTONE	NEW WELL	350 BOPD, 24% WATER
CANADA	OIL	2700-3700 M	VERTICAL	WS	CARBONATES	100% WATER	475 BOPD, 35 WATER
USA	OIL/GAS	3200-4100 M	VERTICAL	OBC	TIGHT SAND	NO PROD - 80 YEARS OLD	1060 BOPD, 250 MMSCF
USA	OIL	3300-3900 M	25 DEG	WS	SANDSTONE	100% WATER	250 BOPD, 20% WATER

Do something awesome. ***Think Quad. Get Results.***